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An Update to the Universal Risk Scales – A Tool for Developing Risk Criteria by Consensus
How safe is safe enough?

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Abstract

In 1999, the Risk-Based Explosives Safety Criteria Team (RBESCT) developed the Universal Risk Scales (URS) to assist in the job of selecting appropriate criteria for defining "How safe is safe enough?" To answer this question, the URS provides two types of numerical data plotted alongside a logarithmic scale. On the left side, the URS summarizes legal precedents and standards that contain criteria for risk acceptance and compares those standard criteria to numerous data on the right side representing actual risk statistics derived from historical accident data. The URS was the foundation for selection of the risk criteria currently used by Department of Defense Explosive Safety Board (DDESB) to evaluate risk-based explosives safety siting assessments. In 2014, A-P-T Research (APT), with guidance from the RBESCT, was tasked to update the URS to reflect changes in the safety culture since the initial study. More current data were collected to update risk values from the previously used activities, and new activities were researched in an attempt to better represent risks similar to the explosives industry. In addition, all standards mentioned in the initial study were compared to see if any updates were made, and new standards were included in the comparison. This research will be evaluated and assessed by the RBESCT and DDESB to determine if current Department of Defense (DoD) site planning criteria need revision. This paper provides the details of this update along with additional perspectives and comparisons with the updated and new data. This updated URS data also has many other potential uses within government and industry for decision makers who face the challenging question of "how safe is safe enough?"

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1 Purpose

The URS scales are designed to give decision makers comparative risk information to address the question, “How safe is safe enough?” The original URS scales included statistical data that had aged for 15 years and needed updating with current information. The purpose of this paper is to update the URS scales with more recent statistical data.

2 Introduction

In 1999, the United States (US) DoD sponsored the initial development of risk criteria for use in risk-based management of explosive materials. Initially, these criteria were to be used on a trial basis only for decisions associated with siting of explosives facilities. To support the development of these criteria, various data relating to risk acceptability were gathered from a variety of sources. To be compared, these data needed to be accumulated in a common format, which led to the development of the URS.

The URS proved to be a valuable tool for reaching consensus within the RBESCT on the risk criteria used for siting explosive facilities. The scales have been used to compare relevant data in order to assist policy makers to select appropriate risk-related criteria in other areas. As the use of risk-based techniques expands within the area of explosives safety and into other areas where hazards to the public reside, a need for further research has been identified to develop risk criteria applicable to these areas. This paper provides an update on the RBESCT’s continuing research into the fundamental question “How safe is safe enough?”

In 2014, the RBESCT tasked APT to update the URS. With guidance from the US DoD, APT researched fatality statistics to update the data currently in the URS with more recent and representative risk values. The actual risk experience of each existing data set in the URS was reanalyzed and new risk values were determined by researching up-to-date injury and fatality statistics. New risk experiences were also researched in order to find groups with numbers more representative of DoD explosives scenarios. This allows for a more direct comparison of risk experiences to personnel working in the DoD explosives and similar industries. Also updated were the regulatory standards used to determine risk criteria for personnel in similar fields. The standards referenced in Technical Paper (TP)-14 Revision 4 were examined to see if there were any updates to that particular entity’s acceptance of individual or group risk.

Combining the analysis of the updated actual risk experience with analysis of the updated regulations and comparing actual data to established criteria may give the RBESCT better insight into potential changes to future risk-based explosives safety criteria. With these data, the RBESCT and DDESB aim to conclude whether or not current DDESB explosives safety siting criteria are overly conservative, with consideration of a potential need to adjust the acceptable risk values to more realistic and achievable levels. It is also worth noting that in the intervening years, the URS has been recognized by other safety communities as a useful tool for decision makers. This update should, as a byproduct, enhance the broader use of the tool.

3 The URS Format

The answer to the question “How safe is safe enough?” is an essential ingredient in establishing any risk criterion. Though the question is fundamental to achieving the practical goal of establishing risk criteria, it is also a somewhat philosophical question in that it requires individuals to make subjective interpretations of legal precedents, societal values, and past risk experiences. Opinions vary widely as to what types of information should be considered when making these judgments, and these differences of opinion become more pronounced when the relative importance of individual data points is considered. For this reason, consensus decisions regarding risk criteria are particularly difficult to achieve. To facilitate decisions of this type, the URS was developed to display on a single scale a wide variety of information for the purpose of comparison. The intent is to display as much information as practical, with the hope that the individual participants in the decision will find among the data information they consider relevant. There are two primary types of information shown on the URS. The first (shown on the left side) is various risk-related legal precedents and governmental standards that may be considered relevant to the case at hand; the second type (shown on the right) is real-world statistical data derived from documented accident experience.

The URS format shown in Figure 1 can display both the risk standards and the actual accident experience plotted as data points on the same scale.

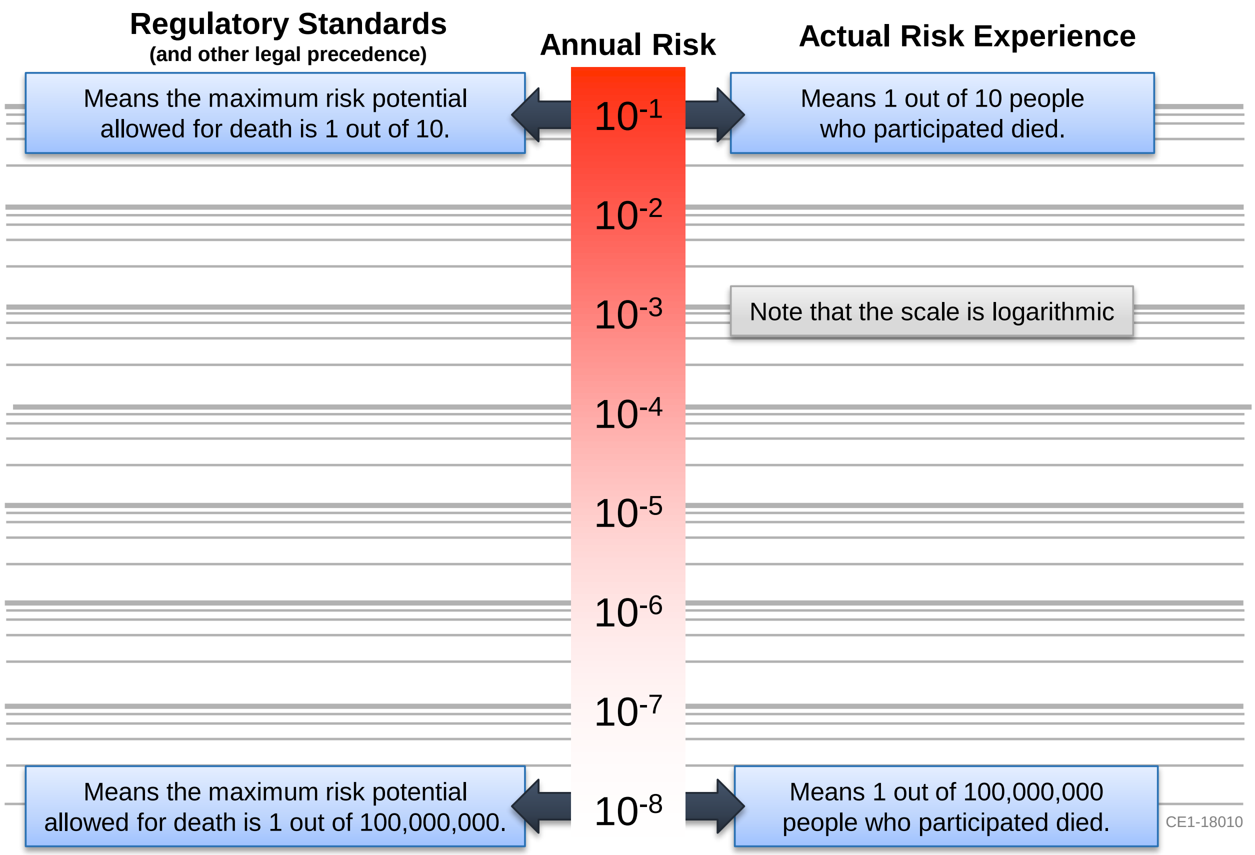

Figure 1: URS Format

A logarithmic scale was chosen because it can display a wide variety of disparate data and allows the aggregate weight of the individual data points to be viewed at once. This scale also enables large differences in the amount of actual risk to be displayed in a small presentation space. For instance, the difference between the values of zero and one on a linear scale is small; in fact, most people think of this numerical space in linear terms of percent. The linear paradigm, however, does not provide the necessary perspective for a useful understanding of the concept of risk. Measured risk is better viewed logarithmically, as orders of magnitude, to allow comparisons of relative risk. The URS format attempts to achieve this perspective so that the concept of relative risk can be more readily understood. In Sections 6 and 7, four sets of data are shown in this format: voluntary (individual), voluntary (group), involuntary (individual), and involuntary (group).

4 The RBESCT Risk Criteria

In the course of its research and deliberations, the RBESCT initially developed a set of four risk criteria for managing explosives risk at DoD facilities. The initial advisory criteria are shown in Table 1 along with the current DDESB criteria values used for explosives safety siting at DoD facilities.

Table 1: Risk Criteria Developed by the RBESCT

Risk To:	Initial Criteria (1999):	Current Criteria (2015)
Any 1 Worker (Annual P_f) Individual Voluntary	Limit maximum risk to 1E-04	Limit to maximum risk of 1E-04
All Workers (Annual E_f) Group Voluntary	Attempt to lower risk to 1E-03 Accept above 1E-02 with significant national need	Limit to maximum risk of 1E-03
Any 1 Person (Annual P_f) Individual Involuntary	Limit maximum risk to 1E-06	Limit to maximum risk of 1E-06
All Public (Annual E_f) Group Involuntary	Attempt to lower risk to 1E-05 Accept above 1E-03 with significant national need	Limit to maximum risk of 1E-05

5 The Raw Data—Old vs. New

In Table 2 and Table 3, numerical risk values are shown for a variety of activities. Each table defines the activity analyzed, and for both the individual risk calculations and expected fatality numbers for each activity, the values from the initial study are given as well as the new values obtained during this study. In addition, the deltas are shown to indicate which activities had the most significant changes since the risk values were last calculated in 1999. It should be noted that some activities do not have old values associated with them. Such instances indicate a new activity was researched that was not included in the initial study. Conversely, there are instances where activities assessed in the initial study did not yield conclusive results when looked at during this study. No change is needed for other data, such as Russian Roulette for example, where the odds of dying while playing (1 in 6) offer a commonly known risk for which no actual death data is available to compare with other activities.

Table 2: Voluntary/Worker Risk Values

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year (Old)	Number of Fatalities Avg/Year (New)	% Change E_f	Data range of revised study
Space vehicle crew member (US)	2.76E-02	2.00E-02	-27.82%	0.47	0.38	-19.62%	1967-2011
Hang gliding (US)	8.48E-04	3.37E-04	-60.25%	7	3.33	-52.43%	2013-2014
Mining and quarrying (US)	2.72E-04	2.12E-04	-21.94%	169	157.40	-6.86%	2003-2012
Motor vehicle accidents (US)	1.62E-04	1.15E-04	-29.23%	43,000	35,469.50	-17.51%	2008-2012
Construction worker (US)	1.55E-04	1.06E-04	-31.63%	957	1,022.60	6.85%	2003-2012
Parachuting/Sky diving (US)	1.26E-04	4.95E-05	-60.68%	39	24.55	-37.05%	2004-2015
Suicide (US)	1.18E-04	1.21E-04	2.48%	31,022	37,102.67	19.60%	2008-2010
All job related (US)	4.00E-05	3.56E-05	-11.12%	5,076	4,745.25	-6.52%	1993-2012
Government (Federal, State & Local US)	3.00E-05	2.14E-05	-28.83%	543	430.10	-20.79%	1993-2012
Air Transportation (US)	3.91E-06	1.69E-06	-56.75%	1,009	519	-48.53%	2008-2010
Football (US)	7.78E-06	4.99E-07	-61.73%	14	4.17	-70.79%	1990-2012
Accidental Drowning – Bathtub (US)	1.23E-06	1.41E-06	14.59%	317	400.25	26.26%	1992-2010
Climbing Mt. Annapurna	3.98E-01	1.65E-01	-58.61%	0.98	1.00	2.56%	1990-2003
Going Over Niagara Fall in a Barrel	2.00E-01	2.00E-01	0%	0.03	It is illegal to go over Niagara Falls. Data is no longer collected		1901-2014

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year (Old)	Number of Fatalities Avg/Year (New)	% Change E_f	Data range of revised study
Russian Roulette	1.67E-01	1.67E-01	0%	Fatality data is not collected for this category			
Commercial Fishing	1.55E-03	1.24E-03	-20%	No exposure data available	46.00	N/A	2000-2010
Logging (US)	1.33E-03	2.16E-03	62.60%	No population data for this category	79.00	N/A	2011-2014
Agriculture (US)	2.40E-04	2.76E-04	15.03%	789	599.30	-24.04%	2003-2012
Manufacturing (US)	4.00E-05	2.21E-05	-44.73%	694	344.70	-50.33%	2003-2012
Hostile Actions (US Military)	1.57E-05	1.24E-04	690.32%	30	216.18	620.61%	1989-2010
Surgical Medical Complications (see notes)	1.04E-05	1.50E-04	1345.31%	2,670	2565.33	-3.92%	2008-2010
The following activities are new for the current revision and were not included in the initial study							
Fixed site amusement ride	N/A	9.56E-09	N/A	N/A	2.56	N/A	1987-2004
US Military Accidents	N/A	3.36E-04	N/A	N/A	584.86	N/A	1989-2010
Oil and Gas Extraction (GOM Rigs)	N/A	1.32E-03	N/A	N/A	7.82	N/A	1996-2006

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year (Old)	Number of Fatalities Avg/Year (New)	% Change E_f	Data range of revised study
Oil and Gas Extraction (total) (this population is exclusive of the GOM activity)	N/A	6.18E-04	N/A	N/A	107.25	N/A	2009-2012
Chemical manufacturing	N/A	2.75E-05	N/A	N/A	22.00	N/A	2008-2014
Pipeline transportation	N/A	1.51E-04	N/A	N/A	6.81	N/A	2003-2011
All mining	N/A	1.23E-04	N/A	N/A	46	N/A	2008-2014
Metal and Nonmetal mining	N/A	8.67E-05	N/A	N/A	21	N/A	2008-2014
Coal mining	N/A	1.90E-04	N/A	N/A	25.00	N/A	2008-2014
Truck transportation	N/A	2.39E-04	N/A	N/A	457.60	N/A	2008-2012

Table 3: Involuntary/Public Risk Values

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year E_f (Old)	Number of Fatalities Avg/Year E_f (New)	% Change E_f	Data Range of revised study
Mortality Rate (US)	8.73E-03	8.14E-03	-6.76%	2,271,966	2,416,736	6.37%	1998-2013
Cardiovascular Disease (US)	2.79E-03	1.93E-03	-30.70%	732,885	597,689	-18.45%	2010

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year E_f (Old)	Number of Fatalities Avg/Year E_f (New)	% Change E_f	Data Range of revised study
Mortality Rate (US Military) - All	1.43E-03	8.69E-04	-39.22%	1,692	1,329	-21.45%	1989-2010
Mortality Rate (US Military) - Accident	N/A	3.83E-04	N/A	N/A	585	N/A	1989-2010
Cerebrovascular Disease (Stroke)	5.96E-04	5.51E-04	-7.58%	156,624	154,694	-1.23%	1990-2010
Stroke (Canada)	4.81E-04	4.14E-04	-13.96%	15,537	13,789	-11.25%	2005-2009
Emphysema (US)	3.83E-04	4.13E-04	7.86%	101,628	119,832	17.91%	1996-2010
Homicide (US)	9.74E-05	5.88E-05	-39.71%	25,115	17,534	-30.19%	2002-2010
Homicide (Washington D.C.)	5.98E-04	3.12E-04	-47.77%	325	183	-43.60%	2000-2012
Homicide (New York City)	1.86E-04	6.54E-05	-64.91%	1,397	536	-61.62%	2000-2013
Homicide (Los Angeles County)	1.49E-04	1.30E-04	-12.75%	1,398	1,222	-12.59%	1989-2010
Falls (US)	5.32E-05	7.46E-05	40.40%	14,100	22,069	56.52%	2000-2010
Unintentional firearm (US)	5.44E-06	2.19E-06	-57.63%	1,429	650	-54.51%	2003-2012
Hypothermia (US)	2.37E-06	2.71E-06	14.44%	611	689	12.77%	1979-2002
Tornados (Alabama)	1.81E-06	3.40E-06	87.62%	7	15	119.78%	1989-2014

Activity	Individual Risk Value P_f (Old)	Individual Risk Value P_f (New)	% Change P_f	Number of Fatalities Avg/Year E_f (Old)	Number of Fatalities Avg/Year E_f (New)	% Change E_f	Data Range of revised study
Tornados (US)	4.08E-07	2.69E-07	-33.95 %	88	76	-13.18 %	1989-2013
Bombing (US)	2.77E-07	8.07E-08	-70.89 %	71	23	-67.61 %	1990-2013
Lightning (US)	2.52E-07	1.55E-07	-38.69 %	65	47	-27.69 %	2006-2010
Snake, Lizard, Spider bites (US)	2.72E-08	2.20E-08	-18.97 %	7	6	-10.71 %	1992-2010
Poisoning (US)	3.92E-05	6.33E-05	61.55 %	10,400	17,867	71.80 %	1989-2012
Suffocation by Ingested Object	1.13E-05	1.04E-05	-8.06%	3,000	3,075	2.49%	2000-2010
Hurricanes (US)	N/A	1.90E-07	N/A	N/A	54	N/A	1989-2013
Malignant Neoplasm (Cancer)	2.04E-03	1.91E-03	-6.29%	536,922	549,517	2.35%	1994 - 2010
Floods	3.69E-07	2.89E-07	-21.49 %	95	82	-13.64 %	1989-2013
Radiation	2.33E-09	1.77E-09	-23.99 %	0.6	0.50	-16.67 %	1991-2010
Explosion and Rupture of Pressurized Devices	N/A	8.48E-08	N/A	N/A	26	N/A	2008-2010
Fireworks Discharge	N/A	1.20E-08	N/A	N/A	4	N/A	2008-2010
Exposure to Smoke, Fire, Flames	N/A	9.18E-06	N/A	N/A	2,817	N/A	2008-2010

Analysis Notes:

1) In updating the data, every effort was made to keep the reference data sets consistent with those of the previous study, i.e., within a given row, the same population and data source were used. In a few isolated cases, statistics were gathered using different sources. In those cases, both the numerator and denominator were derived from the same source to ensure data self-consistency. It should be noted that the later study is more concise in some areas due to better availability of data than in previous studies.

2) In a few cases, the denominator (population) was changed to a more appropriate source. As an example, the entire population of the United States was used as the population in Motor Vehicle Accidents (if you ride in a vehicle, you are subject to a certain amount of risk, and nearly all people at some point ride in a motor vehicle). In contrast, only the population of astronauts that have travelled to space was considered for its category assuming that an astronaut is only subjected to space flight risk when going into space vs. the larger population of astronauts awaiting flights at NASA.

3) The method of calculating exposure figures differed from the initial studies in a few instances. For example, in fatalities due to surgical/medical complications, this study determined the denominator (exposed population) to be the number of surgical procedures performed during the evaluation period, whereas the previous studies defined the exposed population as the averaged general U.S. population. The reason for this change is that data for the number of surgical procedures was not available during the initial study and the change provides a more meaningful data point. The risk remained relatively unchanged in the majority of instances.

Analyst Observations

The calculated risk and changes in the later study can result in many questions about cause and effect. Our research has led to an explanation to some of these questions as explained below.

- Military fatality statistics drastically increased as a result in the increase of military activity worldwide since September 2001.
- The Alabama tornado statistics include the super outbreak of 2011, which caused a significant increase in that category.
- Bombing fatality statistics in this study do not include the terrorist attacks of September 11, 2001. For further clarification, the bombing fatality statistics include only those attributable to the FBI definition of a bomb.
- The risk values associated with surgical complications changed significantly due to changing the population to the number of surgeries performed (as compared to the overall population of the U.S.). This data was not available during the initial study, therefore the calculated risk of new vs. old is not directly comparable.
- The Oil and Gas Extraction (Gulf of Mexico) and Oil and Gas Extraction (total) activities are different data sets and populations.
- The poisoning category includes drug overdoses (both legal and illegal drugs), alcohol poisoning, organic solvents and halogenated hydrocarbons and their vapors, other gasses and vapors, pesticides, and other chemical and noxious substance poisoning.
- The data for Football (US) only includes school-sanctioned football using full protective equipment. There were three known fatalities among sandlot participants from 2009 to 2014 that were not included in these statistics due to a lack of precision regarding the number of participants.

6 Voluntary Risks—Individual Risk (P_f) and Expected Fatalities (E_f)

The following scales illustrate the protection criteria (on the left) and historical risk data (on the right) for voluntary activities. These scales are labeled as “voluntary” because the risk is accepted as a voluntary action taken by an individual. For example, when a person accepts a job with known risks (e.g., a construction worker) it is “voluntary.” Figure 2 plots the data on a URS in terms of each activity’s risk level. Figure 3 shows group risk criteria (on the left) and is expressed in terms of expected fatalities (on the right).

The following paragraphs briefly describe each data point. It should be noted that for better clarity due to space restrictions, not all data points were plotted in the following figures. The complete set of values is contained in Table 2 and Table 3.

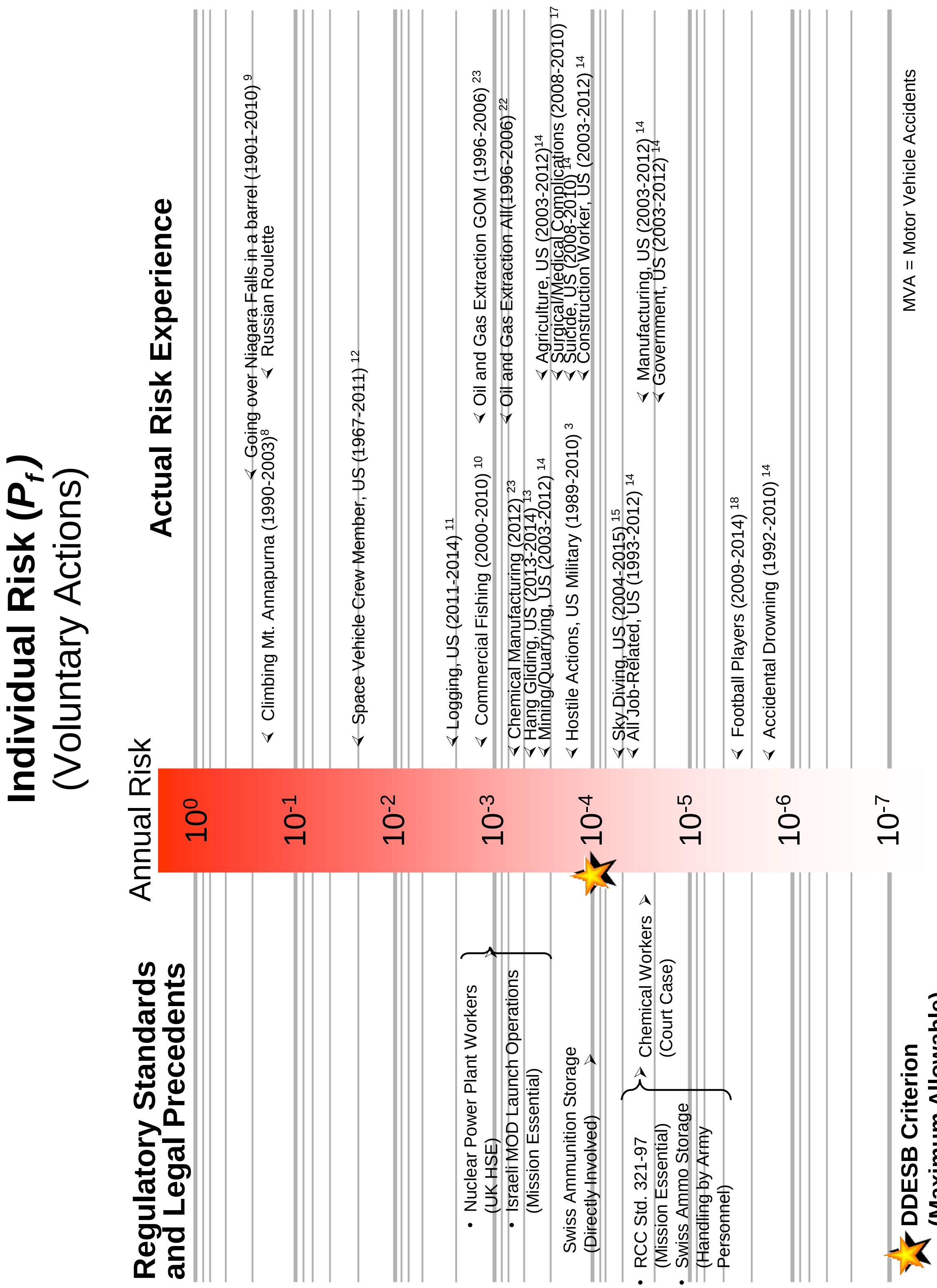

Figure 2: Individual Voluntary (Workers) URS

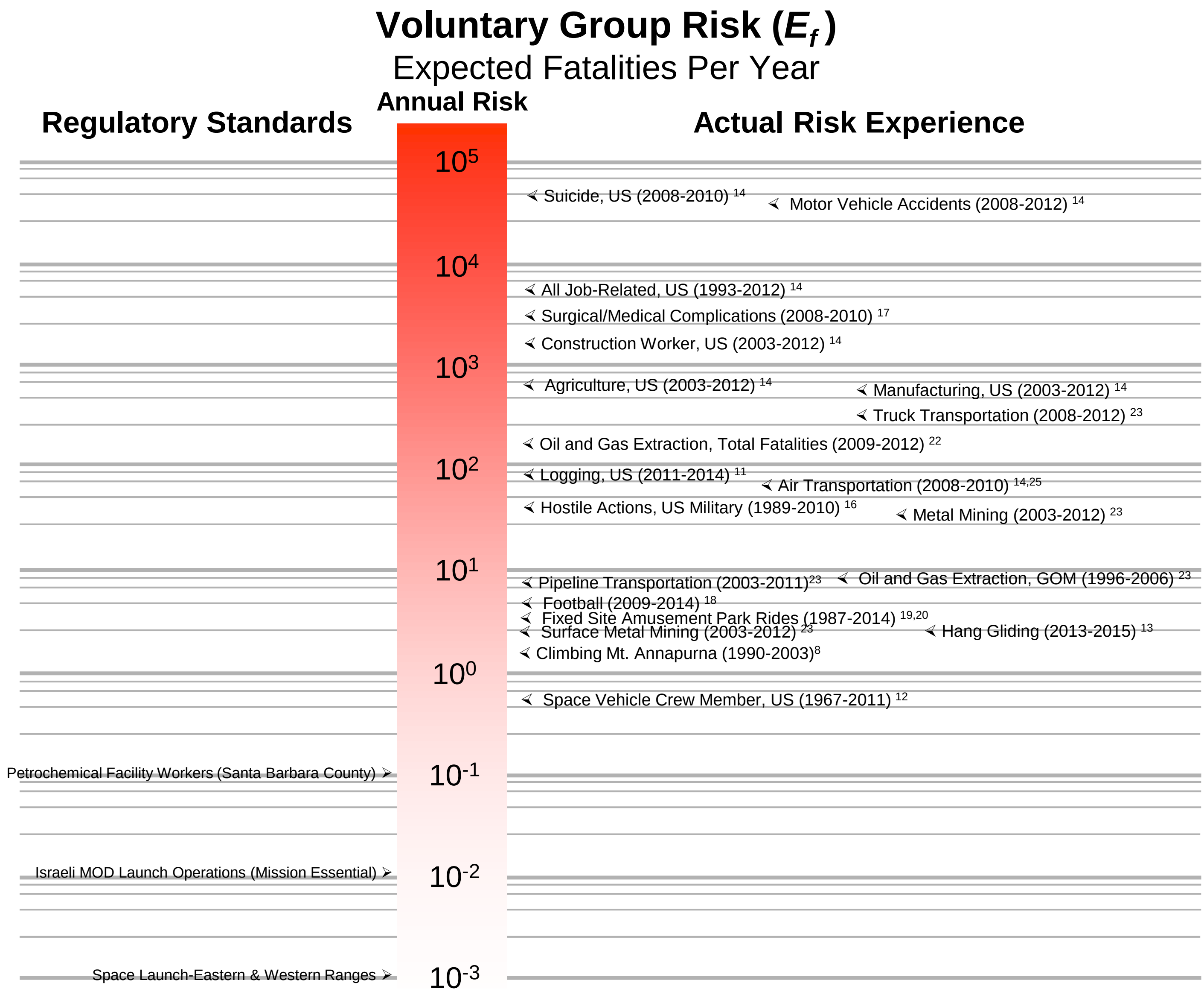

Figure 3: Voluntary Number of Fatalities

6.1 Regulatory Standards

- Nuclear Power Plant Workers (UK HSE) – 1.00E-03.In the *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations*, this is stated as the "suggested maximum tolerable risk to workers in any industry…about the most risk that is ordinarily accepted under modern conditions for workers in the UK and it seems reasonable to adopt it as the dividing line between what is just tolerable and what is intolerable." In 2002, HSE released *Reducing Risk, Protecting People (R2P2)* which gives insight to HSE's decision-making process and method for which it applies control of risk at nuclear power stations. *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations* served as the framework for this document. *R2P2* looks at developments and influences of the industry, changes in the regulatory environment, and changes in the preferences, values, and expectations of society. The 1.00E-03 value remains the standard acceptable risk criteria for individual workers.[1,2]

- HSE Explosives Operations (UK HSE) – 1.00E-03.This value is set for explosive installations as the maximum allowable risk to the individual workers.[3]

- Israeli MOD Launch Operations (Mission Essential) – 1.00E-03. From the RCC Supplement to Standard 321-10, "*Common Risk Criteria for National Ranges: Inert Debris*," this is the number used by the Israeli Ministry of Defense as an annual individual risk criterion for mission essential workers.[4,5]

- Swiss Ammunition Storage – 1.00E-04. From the Swiss Technical Requirements for Storage of Ammunition (TLM 75), Part 2, Appendix 8-2, this is the maximum allowable individual fatality risk per year for directly involved persons.[6]

- Swiss Ammunition Storage (Handling by Army Personnel) – 3.00E-05. From the Swiss Technical Requirements for Storage of Ammunition (TLM 75), Part 2, Appendix 8-2, this is the maximum allowable individual fatality risk per year for Army personnel handling ammunition and explosives.[6]

- RCC Supplement to Standard 321-10 (Mission Essential) – 3.00E-05. From the RCC Supplement to Standard 321-10, "*Common Risk Criteria for National Ranges: Inert Debris*," this is the individual annual risk for mission essential personnel from the commonality criteria for national ranges, expressed in terms of expected fatalities.[5]

- Chemical Risks to Workers (Court Case) – 2.20E-05. The Occupational Safety and Health Administration regulates chemical risks when it can be shown that they pose a "significant risk." In the Supreme Court decision from the case of Industrial Union Department v. American Petroleum Institute, 448 U.S. 607 (1980), Justice Stevens stated that " … if the odds are one in a thousand … a reasonable person might well consider the risk significant and take appropriate steps to decrease or eliminate it." Based on a working lifetime of 45 years, this translates into an annual individual risk of 2.2 x 10-5. (Reproduced from the ACTA report to the Air Force, "Acceptable Risk Criteria for Launches from National Ranges: Rationale.")[7]

6.2 Actual Risk Experience

- Going Over Niagara Falls in a Barrel – 2.00E-01. Since 1901 there have been 15 daredevil attempts to negotiate Niagara/American Falls in a barrel-type floatation device. Of these attempts, three (20%) resulted in the death of the daredevil. (Stunting at the falls now carries a maximum fine of $10,000.) No new barrel attempts have been documented.9

- Russian Roulette – *1.67E*-01. Playing one round only, using a six-shot revolver, the chance of fatality is one-in-six.
- Climbing Annapurna – 1.65E-01. Prior to the arrival of commercial expeditions in the 1990s, the fatality rate of summit attempts was approximately 39.8% (39 fatalities/98 total summit attempts). However, since 1990 advancements in the safety of climbing have reduced the number of fatalities. Between 1990 and 2003 there were 71 successful summit attempts with others resulting in 14 fatalities. Since the increase in safety awareness, the fatality rate per summit attempt is 16.5% (14/85).8
- Space Vehicle Crew Member (NASA) – 2.00E-02. Obtained from www.nasa.gov statistics, between the years of 1967-2011, 17 astronauts died as a result of mission-related spaceflight. Values were obtained using the total number of manned missions from the Apollo, Skylab, and Shuttle missions and the fatalities that occurred during those operations (includes Apollo 1 fatalities which occurred during launch rehearsal). The average number of space vehicle crew member deaths per year has been 0.38 with an average annual population size of 19.[12]
- Timber Cutters (US) – 2.16E-03. According to the Bureau of Labor Statistics, an annual average of 79 loggers were killed between 2011 and 2014. This was out of an average population of 36,530.[11]
- Oil and Gas Extraction (Gulf of Mexico Rig) – 1.32E-03. According to the Bureau of Safety and Environmental Enforcement, there were an average of eight oil and gas-related fatalities from 1996 to 2006 out of an approximate annual exposed population of 5,930 workers.[23]
- Commercial Fishing (US) – 1.24E-03. According to the Centers for Disease Control – National Institute of Occupational Safety and Health, an annual average of 46 fishermen died between 2000 and 2010 out of an average population of 37,097 workers, making it toward the top of the list of high-risk occupations.[10]
- Oil and Gas Extraction (All) – 6.18E-04. According to the Mine Safety and Health Administration, an average of 107 deaths occurred each year from 2009 to 2012 out of an annual exposed population of 173,475.[22]
- Military Accidents (US) – 3.36E-04. According to statistics from the Defense Manpower Data Center, an average of 585 casualties occurred as a result of military accidents from 1989 to 2010. This is from a yearly exposed population of approximately 1.74 million active duty military personnel.[16] “Casualty” is synonymous with fatality in this case.
- Hang Gliding (U.S.) – 3.37E-04. Based on fatality statistics from the United States Hang Gliding and Paragliding Association (USHPA) and an email to the author from USHPA regarding hang gliding population statistics, an average of two fatalities occur yearly out of an exposed population of 9,874. These figures relate to flights between 2013 and 2015.[13]
- Agriculture (U.S.) – 2.76E-04. For the 10-year period 2003-2012, an average of 599 workers died out of an annual worker population of 2,172,164, according to the National Safety Council *Injury Facts*, 2014 edition.[14]

- Truck Transportation – 2.39E-04. According to the Bureau of Labor Statistics, a yearly average of 458 trucking employees died between 2008 and 2012. This risk value was calculated using normalized incident rates based on hours worked rather than number of employees. A 2,000-hour work year was used to calculate the average annual rate.[23]
- Mining/Quarrying (U.S.) – 2.12E-04. For the 10-year period 2003-2012, an average of 157 mining fatalities occurred out of an annual worker population of 741,055, according to the National Safety Council *Injury Facts*, 2014 edition.[14]
- Coal Mining – 1.90E-04. According to the Mine Safety and Health Administration, an average of 25 coal miners died each year from 2008 to 2014 out of an average annual coal mining population of 131,825. The population set is inclusive of operators and contractor employees.[22]
- Pipeline Transportation – 1.51E-04. According to the Bureau of Labor Statistics, an average of seven pipeline transportation employees died from 2003 to 2011. This was out of an average yearly exposed population of 45,198.[23]
- Surgical/Medical Care Complications (U.S.) – 1.50E-04. According to the Centers for Disease Control and Prevention National Vital Statistics Report, from 2008 to 2010, an average of 2,565 people died each year from surgical or medical care-related incidents out of a total 17.13 million surgical procedures.[17]
- Hostile Actions (U.S. Military) – 1.24E-04. Based on data from the Defense Manpower Data Center there was an average of 216 fatalities per year from 1989 to 2010 out of the 1.74 million active duty members. This number is an increase from previous studies as the conflicts in the Middle East (with U.S. military involvement) have taken place.[16]
- All Mining – 1.23E-04. According to the Mine Safety and Health Administration, an average of 46 miners died each year from 2008 to 2014 out of an average annual mining population of 374,262. The population set is inclusive of operators and contractor employees.[22]
- Suicide (U.S.) – 1.21E-04. There were a reported 37,103 suicides, on average, between 2008 and 2010, out of an average U.S. population of 306,730,670.[14]
- Motor Vehicle Accidents (U.S.) – 1.15E-04. For the period 2008 to 2012, there were 35,470 fatalities for a population of approximately 309,208,000, according to the National Safety Council *Injury Facts*, 2014 edition.[14]
- Construction (U.S.) – 1.06E-04. There were an average of 9,646,535 employed construction workers from 2003 to 2012. In this time span there were 1,023 work-related fatalities.[14]
- Metal and Nonmetal Mining – 8.67E-05. According to the Mine Safety and Health Administration, an average of 21 metal and nonmetal miners died each year from 2008 to 2014 out of an average annual metal and nonmetal mining population of 242,295. The population set is inclusive of operators and contractor employees.[22]
- Parachuting/Sky Diving (U.S.) – 4.95E-05. Based on fatality statistics from the United States Parachute Association (USPA) and an email to the authors from the USPA, an average of 24.55 fatalities occurred per year from 2004-2015 with an annual average skydiver population of approximately 496,333. The population was interpolated from data points provided to the authors in an email from the safety director of the USPA. [15]

- All Job-Related (U.S.) – 3.56E-05. Between 1993 and 2012, there was an average of 4,745 work-related deaths out of an average annual exposed population of 133,481,013.[14]
- Chemical Manufacturing – 2.75E-05. According to the Bureau of Labor Statistics, 22 out of an annual average of 800,100 chemical manufacturing employees died each year from 2008 to 2014.[23]
- Manufacturing (U.S.) –2.21E-05. For the 10-year period 2003-2012, an average of 344 manufacturing-related fatalities occurred out of an average exposed population of 15,597,285 workers. [14]
- Government (U.S.) – 2.14E-05. From 1993 to 2012, an average of 430 government fatalities occurred from the average exposed population of 20,145,199 workers.[14]
- Air Travel (U.S.) – 1.69E-06. According to the National Safety Council, an average of 519 people died each year from 2008-2010. This calculation was derived by taking the population of the activity as the average population of the U.S., 306,730,670, during the same time span.[14,25]
- Accidental Drowning (Non-boating, U.S.) – 1.41E-06. Between 1992 and 2010 an average of 400 people drowned each year out of an average annual population of 283,988,950. An additional 347 people died each year in boating accidents that were not included in this calculation.[14]
- Football Players (U.S.) – 4.99E-07. Based on statistics from the *Annual Survey of Football Injury Research, 1931 – 2013* by F.O. Mueller and Bob Colgate from The American Football Coaches Association, an annual average of four football players die from directly related football injuries out of an estimated 8,200,000 average annual participants. In 1990, no fatalities occurred, which marked a change in societal expectations for football safety. The data gathered for this statistic were from 1990-2012.[18]
- Amusement Park Ride (U.S.) – 9.56E-09. According to the Consumer Product Safety Commission, an average of 2.56 people died as a result of accidents at fixed-site amusement park rides in the United States from 1987 to 2004. The average annual US population during this time was 267,687,890.[20, 25]

7 Involuntary Risks—Individual Risk (P_f) and Expected Fatalities (E_f)

The following scales illustrate the protection criteria (on the left) and historical risk data (on the right) for involuntary activities. These scales are labeled “involuntary” because the risk is not accepted as a voluntary action taken by the individual. For example, victims of homicide, stroke, or tornado generally do not die as the result of a voluntary decision to accept risk. Figure 4 plots the data on a URS in terms of each activity’s annual risk level, and Figure 5 displays the expected annual fatalities for the same activities.

The following paragraphs describe each data point. Note: for better clarity due to space limitations, not all data points were plotted in the following figures. The values for all data points can be seen in Table 2 and Table 3.

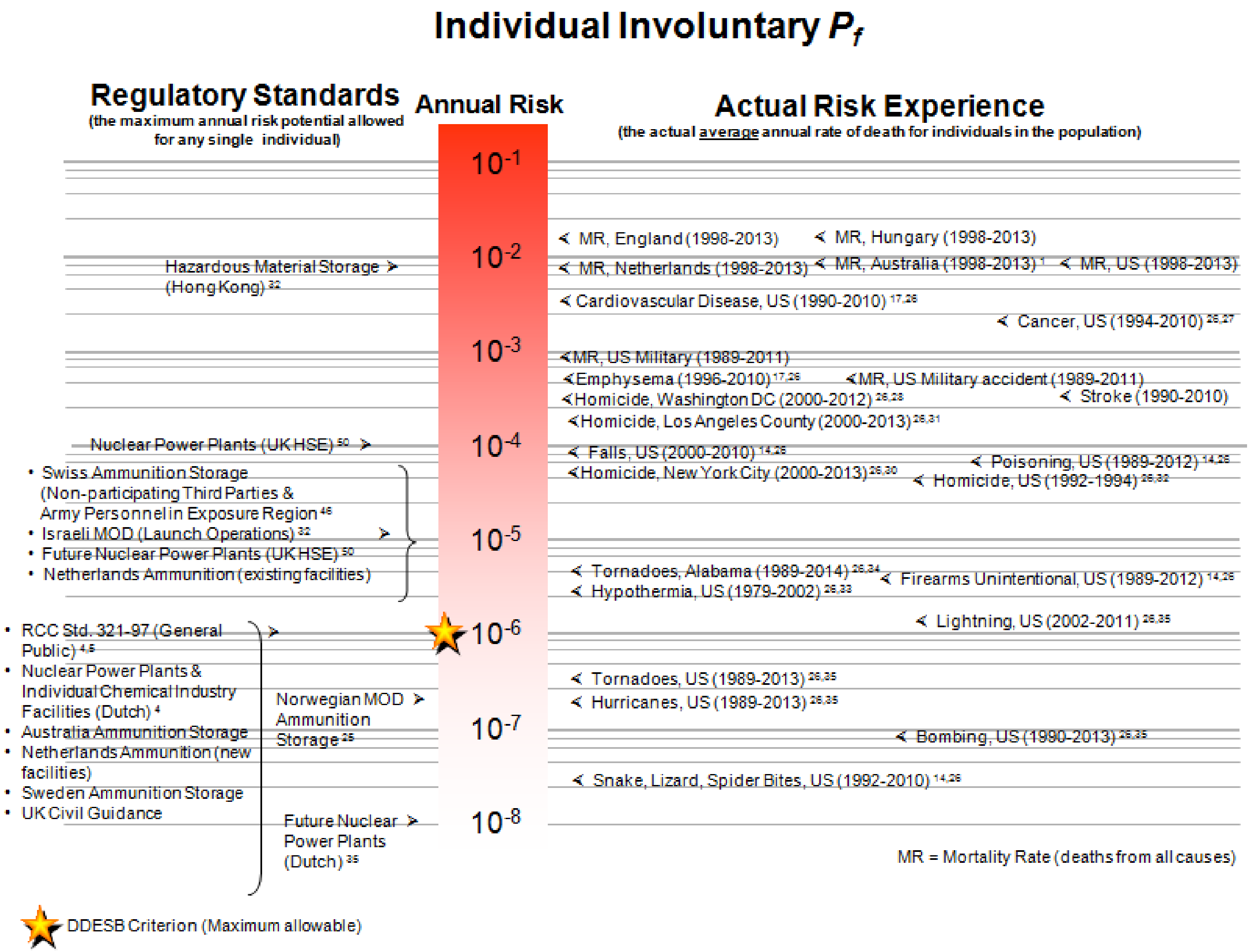

Figure 4: Individual Involuntary Risk

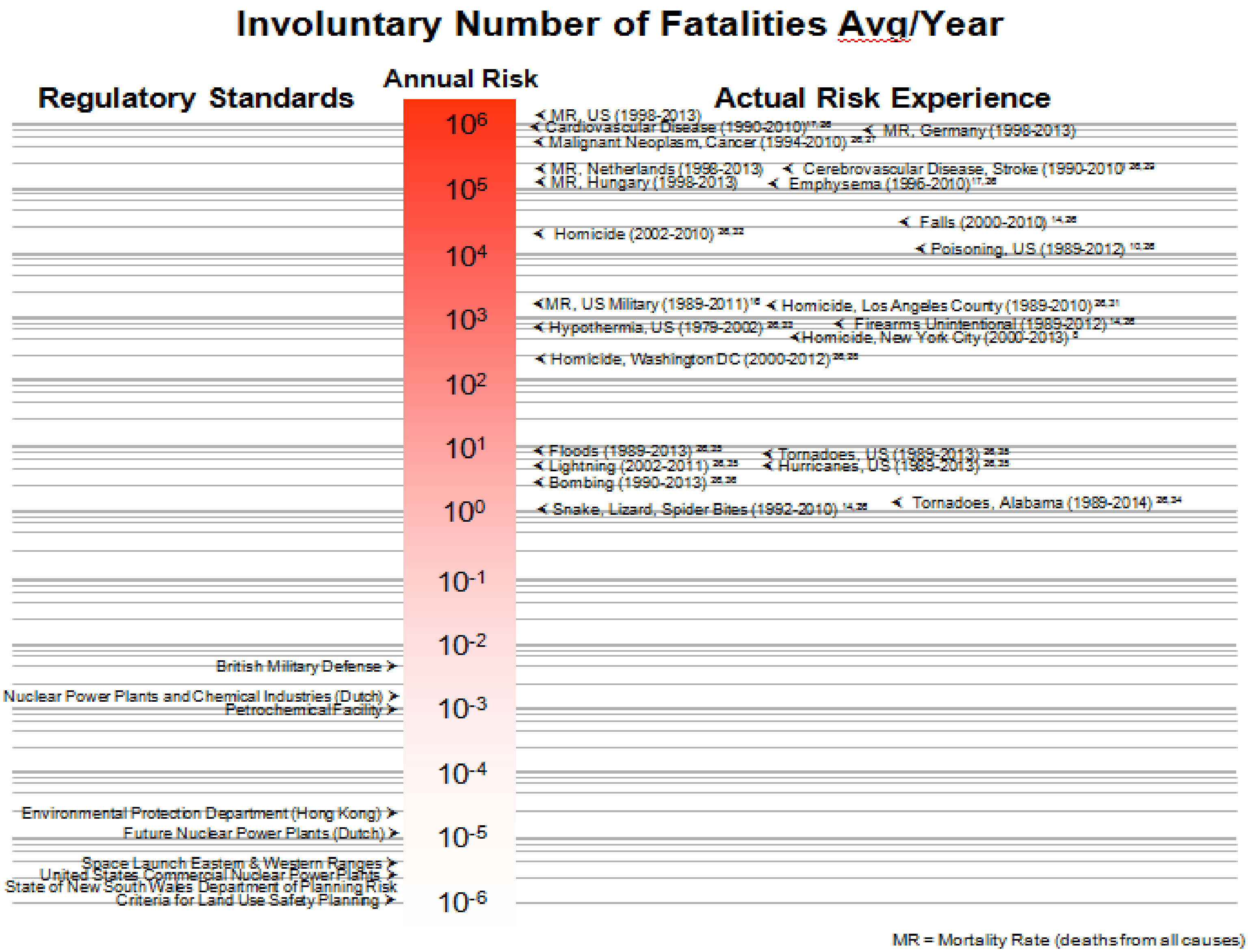

Figure 5: Involuntary Expected Fatalities

7.1 Regulatory Standards

- Nuclear Power Plants (UK HSE) – 1.00E-04. In the *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations*, it states that this is the "suggested maximum tolerable risk to any member of the public from any large-scale industrial hazard." It is further explained that "if the maximum tolerable risk for any worker is set at around 1 in 1000 per annum, it seems right to suggest that the maximum level that we [UK HSE] should be prepared to tolerate for any individual member of the public from any large-scale industrial hazard should be not less than ten times lower, i.e., 1 in 10,000 (1 in 10^4)." In 2002 HSE released *Reducing Risk, Protecting People (R2P2)*, which gives insight to HSE's decision-making process and method that they use to apply control of risk at nuclear power stations. *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations* served as the framework for this document. *R2P2* looks at developments and influences of the industry, changes in the regulatory environment, and changes in the preferences, values, and expectations of society. The 1.00E-04 value remains the standard acceptable risk criteria for individual workers.1[,2]

- HSE Explosives Operations (UK HSE) – 1.00E-04. This value is set for explosive installations as the maximum allowable annual risk to the individual workers.3
- Swiss Ammunition Storage (Non-Participating Third Parties and Army Personnel in Exposure Region) – 1.00E-05. From the Swiss Technical Requirements for Storage of Ammunition (TLM 75), Part 2, Appendix 8-2, this is the maximum allowable individual fatality risk per year for both non-participating third persons and for Army personnel in the exposure region of the facility dealing with ammunition and explosives.6
- Israeli MOD Launch Operations (Uninformed General Public) – 1.00E-05. From the RCC Supplement to Standard 321-02, *Common Risk Criteria for National Ranges: Inert Debris*, this is listed as the number established by the Israeli Ministry of Defense for the maximum annual individual fatality risk from launch operations for the non-participating, uninformed general public. Higher risk levels are tolerated for non-participating, uninformed workers in industrial facilities.5
- Future Nuclear Power Plants (UK HSE) – 1.00E-05. In the *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations*, this is listed as the upper bound of the "range of risk to members of the public living near nuclear installation from normal operations." It is also listed as "the risk of death in an accident at work in the very safest parts of industry." In explanation, "We propose to maintain our existing position that a risk of 1 in 10^4 per annum to any member of the public is the maximum that should be tolerated from any large industrial plant in any industry. But in accordance with Barnes' findings, we propose to adopt a risk of 1 in 10^5 per annum as the benchmark for new nuclear power station in the UK."1
- RCC Supplement to Standard 321-02 (General Public) – 1.00E-06. From the RCC Supplement to Standard 321-02, *Common Risk Criteria for National Ranges: Inert Debris*, this is the individual annual risk for the general public from the commonality criteria for national ranges, expressed in terms of expected fatalities.5
- Nuclear Power Plants (UK HSE – de minimis) 1.00E-06. Although not specifically stated as de minimis in the *UK Health and Safety Executive – The Tolerability of Risk from Nuclear Power Stations*, this is stated as, "the level of risk below which, so long as precautions are maintained, it would not be reasonable to insist on expensive further improvements to standards." It is otherwise stated as "a broadly acceptable risk to an individual of dying from some particular cause." For determining de minimis, the question to ask is whether the risk level is high enough to warrant regulation. As such, risks below this level clearly qualify as de minimis.1
- Nuclear Power Plants & Individual Chemical Industry Facilities (Dutch) – 1.00E-06. From the RCC Supplement to Standard 321-02, *Common Risk Criteria for National Ranges: Inert Debris*, this is listed as the acceptable risk standard used by Dutch industries for public individual fatality; applicable to established nuclear power plants and chemical industries.4

- Norwegian MOD Ammunition Storage – 2.00E-07. From NO (ST) IWP 3-96, *Storage of Ammunition – Quantitative Risk Assessment – Evaluation and Further Approach*, the Norwegian government has specified that this is the maximum permitted risk of death per year for a member of the public due to an accident in an ammunition storage area.

- Future Nuclear Power Plants (Dutch) – 1.00E-08. From the RCC Supplement to Standard 321-02, *Common Risk Criteria for National Ranges: Inert Debris*, this is listed as the acceptable risk standard used by Dutch industries for public individual fatality; applicable to future nuclear power plants.5

7.2 Actual Risk Experience

- Heart Disease (U.S.) –1.93E-03. According to the National Heart, Lung, and Blood Institute, in 2010, 597,689 people died as a result of cardiovascular disease out of an average annual population of 309,300,300.[14, 25]

- Cancer (U.S.) – 1.91E-03. For the 17-year period 1994-2010, an average of 549,517 people died from cancer-related illnesses out of an average annual population of 287,021,180.[14, 25]

- Stroke (U.S.) – 5.51E-04. According to the Centers for Disease Control, between 1990 and 2010 an average of 154,694 people died out of an average annual population of 280,875,710 as a result of cerebrovascular disease.[25, 28]

- Stroke (Canada) – 4.25E-04. According to Statistics Canada, from 2005-2009 and average of 13,963 people died from stroke. This is out of a reported population of 32,837,400.[38]

- Emphysema/COPD (U.S.) – 4.13E-04. According to the Centers for Disease Control and Preventions, *National Vital Statistics Report*, from 1996-2010, 119,832 Americans died from complications of emphysema (chronic obstructive pulmonary disease). This is out of an average population of 289,996,670.[17, 25]

- Homicide (Washington D.C.) – 3.12E-04. According to the Washington, D.C., Metropolitan Police Department, from 2000-2012 an average of 183 people out of a population of 586,891 were the victims of homicide.[25, 27]

- Homicide (Los Angeles County) – 1.30E-04. From 1989 to 2010, the Los Angeles County Sherriff's Department reported that an annual average of 1,222 people out of 9,400,369 were victims of homicide.[30]

- Falls (U.S.) – 7.46E-05. From 2000 to 2010, a yearly average of 22,069 people died from injuries sustained in a fall. This is out of an annual average population of 295,729,090.[14, 25]

- Homicide (New York City) – 6.54E-05. The New York Police Department reported that, between the years 2000 and 2013 an average of 536 people out of an annual average population of 8,196,419 were victims of homicide.[25, 29]

- Poisoning (U.S.) – 6.33E-05. From 1989 to 2012, a yearly average of 17,867 people died from accidental poisoning. This is out of an annual average population of 282,126,670. [14, 25]

- Homicide (U.S.) – 5.88E-05. According to the Centers for Disease Control, from 2002 to 2010, an annual average of 17,534 people out of an average population of 298,432,222 were victims of homicide.[25, 31]

- Suffocation by Ingested Object (U.S.) – 1.04E-05. From 2000 to 2010, a yearly average of 3,075 people died out of an average annual population of 295,729,090 from suffocation by ingested object or by accidental choking. [14, 25]
- Exposure to Smoke, Fire and Flames – 9.18E-06. Between 2008 and 2010, an average of 2,817 people died out of an average annual population of 306,736,700 each year as a result of exposure to smoke, fire, and flames. [14, 25]
- Tornadoes (Alabama) – 3.40E-06. According to statistics published by the National Weather Service Forecast Office, the average number of people who died in Alabama each year from tornadoes, from 1989-2014, was 15. This was out of an average annual population of 4,525,289 as reported by the U.S. Census Bureau.[25, 33]
- Hypothermia (U.S.) – 2.71E-06. According to the Centers for Disease Control and Prevention, from 1979-2002, an average of 689 people died each year from hypothermia. This is out of an average annual population of 253,962,920.[25, 32]
- Firearms – Unintentional (U.S.) – 2.19E-06. In the National Safety Council's *Injury Facts – 2014 Edition*, the average number of people who died each year from unintentional firearm accidents, from 2002-2013, was 662. This was out of an average annual population of 302,351,666 as reported by the U.S. Census Bureau.[14, 25]
- Floods – 2.89E-07. According to the National Weather Service, an average of 82 people died each year between 1989 and 2013 as a result of flooding out of an average annual population of 283,501,600.[25, 34]
- Tornados (U.S.) – 2.69E-07. According to the National Oceanic and Atmospheric Administration Weather Partners, the average number of people who died each year from 1989 to 2013 from tornadic activity was 76 out of an average annual population of 283,501,600 [25, 34]
- Hurricanes (U.S.) – 1.90E-07. According to statistics published by the National Oceanic and Atmospheric Administration, from 1989 to 2013, an average of 54 people died each year from injuries sustained during a hurricane out of an average annual population of 283,501,600.[25, 34]
- Lightning (U.S.) – 1.55E-07. According to the National Center for Health Statistics, from 2006 to 2010, an average of 47 people died each year from lightning strikes out of an average annual population of 303,964,000.[25, 36]
- Explosion and Rupture of Pressurized Devices – 8.48E-08. Between 2008 and 2010, an average of 26 people died each year from an average annual population of 306,736,700 from the rupture of pressurized devices.[14, 25]
- Bombing (U.S.) – 8.07E-08. According to statistics published by the Alcohol, Tobacco, and Firearms (ATF) U.S. Bomb Data Center, from 1990-2013, an average of 23 Americans were killed each year by bombings. The average annual population was 285,030,000 as reported by the U.S. Census Bureau. It should be noted that this statistic includes bombings, attempted bombings, incendiary bombings, stolen explosives, and other categories.[25, 35]

- Snake, Lizard, Spider Bites (U.S.) – 2.20E-08. According to the Safety Council's *Injury Facts – 2014 Edition*, from 1992 to 2010, an average of six people died each year from snake, lizard or spider bites. The average annual population was 283,988,950.[14, 25]
- Fireworks Discharge – 1.20E-08. Between 2008 and 2010, an average of four people out of an average annual population of 306,736,700 died each year from the accidental discharge of a firework or pyrotechnic article.[14, 25]
- Radiation Poisoning – 1.77E-09. Deaths caused by radiation poisoning were extremely rare in the years between 1991 and 2010. Less than one person, on average, died each year out of an average annual population of 282,438,500 as a result of exposure to radiation.[14, 25]

8 Recommendations for Future Updates

1. After completing the initial URS study, updating it multiple times, and using it in evaluations and analyses for 15 years, APT recommends the URS for group risk not be updated after this publication due to inherent subjectivity in determination of population size. While the data are of academic interest, group risk is not useful for decision making because the groups analyzed are of such dissimilar size (varying from tens to hundred millions), so comparisons have little utility. In contrast, individual risks are widely applicable and should be updated with regular frequency (every 5-10 years).
2. Other groups of safety professionals such as those in system safety have shown interest in using this data for decision making, and the DDESB can gain favorable publicity by footnoting the origin of this work and encouraging a wider use by safety professionals.

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